The reliability and validity of a submaximal warm-up test for monitoring training status in professional soccer players

ABSTRACT

Two studies were conducted to assess the reliability and validity of a submaximal warm-up test (SWT) in professional soccer players. For the reliability study, 12 male players performed SWT over three trials, with one week between trials. For the validity study, 14 players of the same team performed SWT and 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$) 7 days apart. Week-to-week reliability in selected heart rate (HR) responses [exercise HR (HR_{ex}), HR recovery (HRR) expressed as the number of beats recovered within 1 min (HRR_{60s}) and expressed as the mean HR during 1 min (HR_{post1})], were determined using intraclass correlation coefficient (ICC) and typical error of measurement expressed as coefficient of variation (CV). The relationships between HR measures derived from SWT and the maximal speed reached at the $30\text{-}15_{IFT}$ (V_{IFT}) were used to assess validity. The range for ICC and CV values were 0.83 to 0.95 and 1.4 to 7.0% in all HR measures, respectively, with the HR_{ex} as the most reliable HR measure of SWT. Inverse *large* (r = -0.50, 90% confidence limits, CL (-0.78; -0.06)) and *very large* (r = -0.76, CL, -0.90; -0.45) relationships were observed between HR_{ex} and HR_{post1} with V_{IFT} in relative (expressed as the % of maximal HR) measures, respectively. SWT is a reliable and valid submaximal test to monitor high-intensity intermittent running fitness in professional soccer players. In addition, the test's short duration (5-min) and simplicity mean that it can be used regularly to assess training status in high-level soccer players.

Key words; heart rate monitoring, high-intensity intermittent running performance, 30-15 Intermittent Fitness Test, exercise heart rate, heart rate recovery

INTRODUCTION

Measurement of soccer players' intermittent endurance running capacity is important given its association with match performance (13, 30), recovery after matches (22, 33) and the risk of injury (28). Moreover, the high variability of high-intensity intermittent running performance across a competitive season (29) means the periodic monitoring of soccer players' training status using valid and reliable tests is important (32). Although maximal tests are sensitive to soccer players' fitness changes and provide valid and reliable measures (2, 5, 11), their application during congested match schedules or periods with limited recovery time means such tests are unpopular with practitioners. Furthermore, the potential influence of mental fatigue from external factors (34) and anecdotal concerns of increased injury risk means top-level soccer players could restrict maximal effort in such tests. Therefore, submaximal tests have been introduced as practical options to monitor soccer players' fitness and fatigue status (4, 8, 10, 12, 15, 20, 21, 23, 29, 31, 35).

The use of heart rate (HR) measures during submaximal running tests, including exercise HR (HR_{ex}) and HR recovery (HRR), are well documented (8, 12, 20, 21, 24, 25, 35). While many running-based submaximal tests have been used to assess reliability, validity or the usefulness of HR measures (1, 4, 8-10, 12, 15, 20, 21, 23-25, 27, 31, 37), these procedures have typically employed long exercise durations or need prior warm-up due to their high intensity. Indeed, longer duration tests of ≥ 6 min with higher final running velocities (i.e. ≥ 14 $km \cdot h^{-1}$) typically provide better estimations of maximal intermittent capacity compared to shorter duration tests of ≤ 4 min (4, 20, 21, 23, 37). Therefore, these tests are unlikely to be employed on a regular basis in professional soccer because of the associated time constraints (6) and high final velocities that mean they are unsuitable in the early phases of a training session (i.e., warm-up). Therefore, developing a simple continuous submaximal test that can be used by practitioners in the early stages of training sessions to monitor the training status of players seems warranted.

An important consideration for a submaximal test is how various measures from heart rate can be used to make interpretations of a player's training status. For example, HR_{ex} is known to be more reliable and also shows a better signal to noise ratio than HRR (6). However, the use of different methods to measure and report HRR, such as the number of beats recorded during 60 seconds (HRR_{60s}) compared with the mean HR during a 60-second recovery (HR_{post1}), might have influenced interpretation of these data (6). It would therefore be of interest to examine more carefully how the calculation of HRR (i.e., HRR_{60s} vs. HR_{post1}) influences the reliability and validity of a short duration submaximal running test in professional soccer players. Accordingly, the purpose of this study was to investigate reliability and validity of specific HR measures (i.e., HR_{ex}, HRR_{60s} and HR_{post1}), when implementing a 5-min submaximal warm-up test (SWT) in professional players.

METHODS

Experimental Approach to the Problem

This investigation comprised two separate studies to assess the reliability and validity of a sub-maximal warm-up test (SWT) in professional soccer players. To assess the reliability of the SWT, players were initially habituated to the SWT protocol and thereafter performed three separate trials of the SWT before training sessions during a three-week period. For the validity study, players performed one trial of the SWT followed by the 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$) seven days later. Submaximal and maximal tests were performed on a day after easy to moderate intensity training sessions. Players provided ratings of perceived wellbeing immediately before all trials to limit the influence of fatigue on performance. The players were asked to maintain regular sleep and nutritional habits, avoiding caffeine at least 2 hours before each testing session. Player hydration status was also measured before each testing session as a part of the usual monitoring process by the performance staff using body mass measurement and self-reported urine color. Both SWT and 30-15_{IFT} were performed on artificial turf at ~11 A.M with similar temperature (24–26°C).

Subjects

All players were male and represented a single professional soccer team competing in the Persian Gulf Cup, with data collected during the in-season phase of the 2015-2016 season. The studies recruited 12 players to assess reliability and 14 players to assess the validity of the SWT (Table 1). All subjects trained 5 to 6 sessions per week with the data collection for both the reliability and validity studies performed in July/August of 2015. All data were measured as part of routine player monitoring during the competitive season and the study was approved by the Ethics Committee of the Faculty of Sport Sciences of the University of Isfahan. All players were informed of the risks and benefits of the study and gave written informed consent to participate in the study. The club also consented to use the data for publication purposes. The study conformed to the recommendations of the Declaration of Helsinki.

*****Table 1 near here*****

Procedures

Perceived wellbeing

Self-reported subjective measures of wellbeing were recorded for each player before each trial. The Hooper questionnaire was used, comprising four questions related to perceived sleep quality, stress, muscle fatigue and soreness (16). Each question was scored on a 7-point scale (with 1 and 7 representing very good and poor wellness ratings, respectively) and the overall wellness determined by summing the four scores (16).

Submaximal warm-up test (SWT)

The SWT required players to run back and forth between two lines placed 100 m apart on a soccer pitch. Players ran for 4 min at 12 $km \cdot h^{-1}$ with a change of direction (COD) every 100 m. Running speed was controlled by an auditory signal from a CD player. After the 4-minute period, players were asked to stop running and stand without any movement to enable recording of heart rate recovery. Heart rate was recorded throughout the test at 1-second intervals using a heart rate monitor (Polar T34, Polar Electro Oy, Kempele, Finland) synchronized to a portable 15 Hz global positioning system (GPS; SPI Pro X, GPSports, Canberra, Australia). The Team AMS software (GPSports, Version 2.1) was later used to conduct the analyses. Heart rate during exercise (HR_{ex}) was computed using the mean heart rate during the last 30-second of the running part of SWT (i.e., from 3:30 to 4:00 min). HRR was calculated in the first 60-second after the cessation of the running part of SWT (i.e., from 4:00 to 5:00) either as the reduction in the number of beats (HRR_{60s}) or the mean HR (HR_{post1}).

The 30-15_{IFT}

The 30-15_{IFT} is a progressive maximal test of high-intensity intermittent running performance and its protocol has been detailed previously (5). Briefly, the 30-15_{IFT} consists of 30-second shuttle runs interspersed with 15-s recovery phases. The starting velocity is 8 km·h^{-1} and increases by 0.5 km·h^{-1} in each stage thereafter. The subjects run back and forth between two lines at 40 m apart. Running speed was governed by an auditory signal with subjects required to be into 3-m zones at each terminus and in the middle of the field when the audio signal sounded. The test ended when a subject could no longer maintain the required running speed or when he was unable to reach a 3-m zone near to each line at the moment of the audio signal on 3 consecutive occasions. The velocity of last completed stage is the maximal performance speed (V_{IFT}). All players were habituated with 30-15_{IFT} during a training session before commencing the study.

Statistical analyses

Data are presented as either means with standard deviation (SD) or means with 90% confidence limits (90% CL) where specified. All HR measures derived from SWT were used in their absolute and relative values (as percentage to maximal HR (HR_{max})) in both the reliability and validity analyses. To examine the reliability of the SWT over three trials, the intraclass correlation coefficient (ICC) and typical error of measurement expressed as coefficient of variation (CV) were computed using a specifically designed spreadsheet (18). ICC results were interpreted based on the classification scale: low (0.26–0.49), moderate (0.50–0.69), high (0.70–0.89) and very high (0.90–1.00) (18). The smallest worthwhile change (SWC) in performance (3) was considered as 2×CV for a given variable to be certain of a real change (36). To evaluate any learning effect within trials in the reliability study, repeated-measures analysis of variance (ANOVA) were performed with the level of significance set at 0.05. In the presence of a statistically significant F ratio, *post-hoc* paired samples *t*-tests were performed to see where differences occurred. These analyses were performed using SPSS for Windows (Version 16.0;

SPSS Inc, Chicago). Validity of SWT HR measure responses was determined using Pearson correlation (17). The magnitude of the correlations (r, 90% confidence limits, CL) was assessed according to the scale of Hopkins (19).

RESULTS

Reliability

The HR responses in 3 trials of the SWT are shown in Table 2. Measures of reliability including CV and ICC are detailed in Table 3. The HR_{ex} and HRR_{60s} showed the highest and the lowest CV values (i.e., 1.4 and 7.0%), respectively. The highest and lowest ICC values were 0.95 and 0.83 for HR_{ex} and $HRR_{60s\%}$, respectively. The SWC of HR_{ex}, HRR_{60s} and HR_{post1} in relative measures were ~ 3, 14 and 6%, respectively. These values translated to a real meaningful change for HR_{ex}, HRR_{60s} and HR_{post1} in absolute measures as ~ 5, 7 and 8 $b{\cdot}min^{-1}$, respectively. Within-subject changes for 3 trials in all measures were not significantly different ($P > 0.05$).

*****Table 2- 3 near here*****

Validity

HR_{post1} showed *very large* inverse relationship with V_{IFT} in its actual and relative values (Figure 1). The relationship of all HR measures with V_{IFT} for determining the validity of HR responses in SWT are shown in Figure 2. HR_{ex} and $HR_{ex\%}$ showed inverse *moderate* (r = - 0.34, 90%CL -0.69; 0.13) and *large* (r = -0.50, -0.78; -0.05) relationships with V_{IFT}, respectively. Both HR_{ex} and HR_{post1} had stronger relationship with V_{IFT} when expressed as their relative values (i.e., % of HR_{max}).

*****Figure 1-2 near here*****

DISCUSSION

This study examined reliability and validity of selected HR measures (HR_{ex}, HRR_{60s} and HR_{post1}) of a submaximal warm-up test (SWT) in professional soccer players. The main findings of the present study were that i) SWT is a valid and reliable tool for monitoring professional soccer players and, ii) HR_{post1} presents the strongest relationship with high-intensity intermittent running performance compared to HR_{ex} and HRR_{60s} derived from a SWT.

Reliability of selected HR measures in SWT

The ICC for the actual and relative HR_{ex} values during the SWT was *very high* (0.95), which is consistent with previous studies reporting ranges between 0.92 and 0.97 (9, 21, 31, 37) but higher than values reported elsewhere (ICC; 0.72-0.89) (27). Similarly, the CV of HR_{ex} during SWT (CV = 1.4%) was in agreement with the reported range of 1.3-2.0% (4, 9, 25, 31, 37), but lower than other studies reporting values of ~3-4 % (10, 12, 21).

The high reliability of HR_{ex} reported in the present study is likely related to the annual phase (i.e., in-season) of the experiment characterized by a lower weekly training load variation and also well monitored wellness status of players before each trial. Indeed, previous studies investigating the reliability of HR measures have usually been conducted during pre-season camps (12) or congested tournament phases (10), when the general load is higher than standard in-season week and more fluctuations in heart rate measures could be expected (6). The protocol of previous submaximal tests in soccer players with the least day to day variation of HR_{ex} (CV: 1.4 to 1.6%) were intermittent with the final velocity of 14 and 14.5 $km \cdot h^{-1}$ at a time point of 6 min (4, 31). Although the time points of 2 and 4 min during the Yo-Yo Intermittent Recovery

Test Level 1-submaximal (Yo-Yo IR1-sub) possessed acceptable reliability in soccer players (ICC range: 0.92-0.93) (21), the velocity was ≥ 13.5 $km \cdot h^{-1}$, suggesting its low practicality for implementing as a warm-up activity. Despite previous recommendations to have high running intensities to observe 85-90% of HR_{max} and have lower 'noise' in measures (24), the lower intensity of SWT as a real submaximal test in our study (i.e., 77% of HR_{max}) was enough to show similar variation. Non-significant differences observed between SWT trials in the present study is not surprising since the speed was low and protocol familiar to participants, thus reducing any potential learning effect. We conclude that the SWT does not require habituation and can be used with players to detect a real change in exercising heart rate.

The CV and ICC for HRR_{60s} reported in our study (7.0% and ~ 0.84, respectively) are in contrast to a recent study in Australian football players (37) that reported 9.2% and 0.94 for CV and ICC, respectively, using a submaximal intermittent running test. Again, any variability in HRR between trials and compared to previous studies are likely to be explained by the use of a different running speeds in these protocols (25) and the effect of prior activity on parasympathetic reactivation (1).

We observed similar reliability for HR_{post1} in the present study compared to the work of Lambert et al. (25) but better than that of Owen et al. (31). Differences in the running speeds used and how HRR was calculated is probably an explanation for the variation from pervious work. Indeed, day to day variations of HRR is index dependent and is pertinent to the analyses method employed (6). The present study also reaffirms previous observation (26) that HR_{post1} is a more reliable measure than HRR_{60s} of measure of recovery index.

Validity of submaximal HR measures in SWT

The correlation between HRR_{60s} and V_{IFT} was *small*, whereas HR_{ex} and HR_{post1} revealed *large* and *very large* associations, respectively, when expressed relative to individual HR_{max} (i.e., $HR_{ex\%}$ and $HR_{post1\%}$, Figure 2). The *large* inverse relationship observed between $HR_{ex\%}$ and V_{IFT} in the present study was in agreement with previous reports of *large* to *very large* inverse relationships with maximal high-intensity intermittent performance in various submaximal tests at 2 min (20, 37), 3 min (37), 4 min (21, 37), 6 min (4, 23) and 9 min (23). Our result was not, however, in agreement with those studies showing only a *moderate* association between maximal high-intensity intermittent performance and $HR_{ex\%}$ after 3 min (23) and 4 min (4, 20) derived from their submaximal tests. Given the limited time available for monitoring soccer players in a real world scenario (7) and a common delay in HR response (HR lag) (14), it seems that 3 to 4 min duration is suitable for a submaximal test to record $HR_{ex\%}$ (6). Among the previous investigations assessing validity of $HR_{ex\%,}$ at 4 min time point, only two studies (21, 37) have shown acceptable associations. Discrepancies with those studies reporting poor associations (i.e. *small* correlations) between submaximal and maximal tests (20) are again attributed to the variations in the final running speeds attained during the submaximal tests. The *small* correlations between HRR_{60s} and maximal speed also confirm previous observations (37) that are probably attributed to the mode of exercise and short duration of the test. Indeed, in similar tests conducted using cycling for a longer duration (26) *large* to *very large* correlations were reported between HRR_{60s} and maximal performance. That HR_{post1} is more strongly associated with high-intensity running than HRR_{60s} is explained by the methods of calculating each variable. When calculating HRR_{60s} only two values are used whereas for HR_{post1} all HR beats during one min of recovery are pooled to provide a mean value (6). The example in Figure 3 illustrates Player 2 had a better performance in V_{IFT} than Player 1 (19.5 vs. 19 $km{\cdot}h^{-1}$) and the same absolute HRR_{60s} (i.e., 53 bpm) that was slightly slower in Player 2 when expressed as % of HR_{max} (26 vs. 24%). However, the HR_{post1} was noticeably lower in Player 2 (128 bpm; 59% HR_{max}) compared to Player 1 (149 bpm; 73% HR_{max}). These data suggest the potential utility of HR_{post1} for predicting high-intensity intermittent running performance in team sport players. All selected HR measures when expressed as a percentage of individual HR_{max} showed slightly stronger associations with maximal performance (Figure 2) which is consistent with previous recommendations to use relative values to track fitness changes (6).

*****Figure 3 near here*****

In conclusion, the present study showed that selected HR measures derived from a simple continuous and submaximal test with a short duration (≤ 5min) has acceptable reliability that is agreeable with faster submaximal tests that have been previously proposed for soccer players (3, 20, 30). Discrepancies between the results of previous studies when evaluating the reliability and validity of HR_{ex} collected at different time points (i.e., 2, 3, 4, 6 and 9 min) (4, 20, 21, 23, 31, 37) may also be related to the submaximal test protocol including its continuous or intermittent nature and the final speed reached as important determinant factors. The results of present study also suggest implementing a continuous protocol with a slower speed may reduce the number of habituation sessions and the feasibility of using of submaximal tests as part of the player monitoring process. The method of calculating HRR when monitoring fitness changes of soccer players could also be an important consideration and it seems that HR_{post1}, particularly when expressed as % of HR_{max} (i.e., $HR_{post1\%}$), is the most relevant HR measure to the high-intensity intermittent running fitness of professional soccer players. To understand if changes in heart rate were meaningful, i.e. attributed to fatigue or adaptive response to training, it is necessary to consider values with respect to the SWC. Using the submaximal test in the present study, we report SWCs for HR_{ex}, HRR_{60s}, HR_{post1} of ~ 5, 7 and 8 $b \cdot min^{-1}$ and ~ 3, 14 and 6% for absolute and relative measures, respectively. Coaches would therefore be advised to use these values to interpret players' data with confidence.

PRACTICAL APPLICATIONS

The SWT provides a valid, reliable and practically useful tool to track high-intensity intermittent running fitness in professional soccer players. In particular, the low speed (12 $km \cdot h^{-1}$), short duration (5 min) and continuous mode of SWT compared to previous proposed intermittent submaximal tests with higher velocities (≥ 13.5 $km \cdot h^{-1}$) (4, 20, 21, 23, 37) suggests this can be regularly used in the early stages of warm-up with team sport players. These important characteristics of the SWT distinguish it from previously introduced submaximal tests that support implementing the test on a regular basis. Among the HR responses during SWT, HR_{ex} and HR_{post1}, particularly when expressed as the percentage of individual HR_{max}, provide the most stable and relevant measures for monitoring high-intensity running performance. Weekly test to test changes more than ~ 5 bpm (3%) in HR_{ex} and 8 bpm (6%) in HRR_{post1} can be considered signs of changes in training status. The advantages of using submaximal tests for monitoring purposes enables the collection of data more frequently, which is particularly useful during busy schedules. Therefore, practitioners are encouraged to use SWT and monitor their soccer players at an individual level and on a weekly basis to optimize training load. The SWT also provides a suitable option for tracking the fitness changes of those injured players not allowed to perform maximally in rehabilitation interventions.

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Acknowledgments

The authors declare no conflict of interest. The results of the present study do not constitute endorsement by the NSCA.

Figures and tables legends

Table 1: Subjects characteristics in reliability and validity studies

.**Table 2**: Heart rate responses of SWT in reliability study

Note. Submaximal Warm-up Test (SWT), the number of beats recovered within 1 min (HRR_{60s}), HR .average during 1-minute recovery (HR_{post1}), Standard deviation (SD)

Table 3: Measures of reliability for SWT in professional soccer players

Note. Submaximal Warm-up Test (SWT), typical error of measurement expressed as a coefficient of variation (CV), intraclass correlation coefficient (ICC), the number of beats recovered within 1 min .(HRR_{60s}), HR average during 1-minute recovery (HR_{post1}), confidence limits (CL)

Figure 1: Pearson correlation coefficient (90% CL) of V_{IFT} ($km \cdot h^{-1}$) and heart rate recovery (HR_{post1}) in absolute (Part A) and relative measures (Part B). Final speed reached during the final stage of 30-15 .intermittent fitness test (V_{IFT}), average HR during 1 min recovery (HR_{post1})

Figure 2: Pearson correlation coefficient (90% CL) of Heart rate (HR) measures versus 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$). Exercise heart rate (HRex), the number of beats recovered within 1 .min (HRR_{60s}), average HR during 1 min recovery (HR_{post1})

Figure 3: Heart rate responses to the submaximal warm up test (SWT) in two representative subjects. Final speed reached during the final stage of 30-15 intermittent fitness test (V_{IFT}), maximal heart rate

(HRmax), exercise heart rate (HRex), the number of beats recovered within 1 min (HRR_{60s}), average HR .during 1 min recovery (HR_{post1})